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Dense Wild Yam Patches Established by Hunter-Gatherer Camps: Beyond the Wild Yam Question, Toward the Historical Ecology of Rainforests

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Introduction

Prior to the 1980s, most researchers believed that the African forest hunter-gatherers, or Pygmies, were the original inhabitants of the central African rainforests. It was assumed that their close social, economic, and ecological relationships with neighboring agricultural societies did not date back long, and that they had previously lived solely through foraging wild forest products. The same is true for forest hunter-gatherers on other continents.

However, Headland (1987) and Bailey *et al*. (1989) noted that no previous studies had produced sound evidence that pure hunter-gatherer subsistence was possible in any rainforests worldwide, and they argued that it was not, and had never been, possible to live in such areas while solely depending on wild products. Although rainforests contain vast numbers of species and huge biomass, consumable resources for humans, especially sources of calories, seem to be scarce and dispersed. Therefore, they argue, hunter-gatherers adapted to live in rainforests only after they began obtaining agricultural crops from cultivators. This hypothesis was called the "wild yam question" by Headland (1987) because the availability of wild yams was considered to be the key factor that determined whether pure hunter-gatherer subsistence in rainforests was viable.

Two opposing arguments have arisen from studies in different regions of the Congo Basin. Hart and Hart (1986) concluded that it was extremely difficult for the Mbuti in the Ituri forest in the eastern Congo Basin to live without agricultural crops, particularly in the dry season and the early rainy season when wild nuts and honey were not available. On the other hand, Bahuchet *et al*. (1991), Hladik and Dounias (1993), and Sato (2001, 2006) argued that for the Aka and Baka in the western Congo Basin enough wild yams existed for their subsistence. These studies were principally based on investigations of the density of wild yams, and lacked detailed descriptions of the use of wild yams. Therefore, the issue of whether exploitation of wild yams, including searching for them, digging them up, transporting them to the camp, and cooking and consuming them, could have been practiced in everyday life remains inconclusive (cf. Bailey and Headland 1991).

Archaeological studies have provided powerful evidence indicating the existence of humans in the African rainforests before the beginning of agriculture (Mercader 2003a, b; Mercader and Martí 2003). Unfortunately, they did not identify the foods upon which the ancient forest hunter-gatherers depended. They referred to ecological and anthropological studies that suggested ancient hunter-gatherers would have eaten wild nuts and meat, both of which were considered to have limited availability (Hart and Hart 1986).

The simplest and most explicit way to demonstrate if and how hunter-gatherers can live on a diet consisting mostly of wild yams is to actually observe it. During fieldwork with the Baka in southeastern Cameroon, I (2006a; 2009a) recorded all of the harvests during long-term and large-scale hunting-and-gathering camps (*molongo* in the Baka language) in the dry and early rainy season, i.e., the period during which the forest was thought to be barren (Hart and Hart 1986), and found that the forest provided a plentiful food supply, 65 % of which (on a calorie basis) was made up of wild yams, and in particular annual species. Furthermore, Sato *et al*. (2012) undertook controlled hunting-and-gathering camping with Baka informants and demonstrated that annual yams are a staple food throughout the year.

However, the question remains as to how yams have become so densely distributed in this area. I (2009a) noted that, within the area containing numerous yam patches, small settlements had been created before the colonial period. Moreover, the forests of Cameroon have been considerably

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disturbed by shifting cultivation for centuries (Chujo 1992; Van Gemerden *et al*. 2003), and contain many trees that prefer a disturbed environment (Yasuoka 2009b). Therefore, it is possible that forest disturbances via shifting cultivation might have affected the distribution of light-demanding annual species of wild yam (Yasuoka 2009a).

It is of interest whether such disturbances were indispensable for the development of sufficient yam patches to support the hunter-gatherers. In 2012, a Baka informant told me that he had passed by *molongo* campsites where around 100 people had consumed numerous yams in 2002 and 2005 (Yasuoka 2006a, 2009a) and found dense distributions of wild yams that had regenerated from the inedible parts of tubers discarded during cooking. Hence, for the present study, I revisited these campsites. By adding quantitative data obtained from previous studies, it was possible to determine whether the actions of hunter-gatherers themselves can generate sufficient yam patches for the annual *molongo* lifestyle simply through the exploitation and subsequent dispersal of wild yams. This examination moves beyond previous issues regarding the notion of pure hunter-gatherer subsistence to the perspective of an historical ecology that focuses on the history of interaction between humans and resources.

People and Study Sites

The Baka make up one of the so-called Pygmy groups scattered across the Congo Basin. Baka territory straddles southeastern Cameroon, northwestern Congo-Brazzaville, and northeastern Gabon, and is covered with rainforest on gently rolling hills at an altitude of 400–600 m above sea level. The vegetation is classified as a mixture of evergreen and moist semideciduous forests (Letouzey 1985a, b) dominated by the families Caesalpinioideae, Mimosoideae, Annonaceae, and Meliaceae (Yasuoka 2009b). The mean annual temperature is around 25 °C and tends to be constant year-round. The mean annual rainfall at Yokadouma is about 1,500 mm. The mean monthly rainfall in the dry season (from December to February) is less than 50 mm, whereas in the rainy season (from March to November) it is normally more than 100 mm, although the months of June and July are typically drier.

Although there has not been a recent census of the Baka population, it is estimated to be around 30,000 in southeastern Cameroon (Njounan Tegomo *et al*. 2012). Thirteen groups of Bantu-speaking cultivators and two groups of Adamawa Eastern-speaking cultivators have close social and economic relationships with the Baka, as is the case with other Pygmy groups (Hewlett 1996). After the 1930s, a French mandate government promoted the sedentarization of both Baka and the cultivators, and this policy was continued by the Cameroonian government after independence in 1960 (Althabe 1965). Starting in the 1970s, the populations began to settle along the country's unpaved highways, and today most Baka live in sedentary settlements along roads, although they spend some months a year in the forest.

I conducted field research in June 2012 in Zoulabot Ancien village, Boumba-Ngoko Department, East Region, Cameroon (Fig. 1). The village is located between two highways, separated by about 150 km and running from north to south in southeastern Cameroon. As of June 2012, it contained four Baka settlements of 191 people comprising 41 households. In addition, the Konabembe, a Bantu group, also live in the village (50 people comprising 12 households), including schoolchildren that spend most of the year in the town. Many of the Konabembe families had moved to villages near Yokadouma in the 1970s, but returned after the construction of a logging road in 2002.

Materials and Methods

Wild Yams on Baka Land

According to previous studies, 15 to 17 species of wild yam (genus *Dioscorea*) and two species of yam-like plants (genus *Dioscoreophyllum*) grow in the forests of Cameroon (Hladik and Dounias 1993; Dumont *et al*. 1994; Hamon *et al*. 1995). Among them, 10 edible species of *Dioscorea* (Table 1) and one edible species of *Dioscoreophyllum* have been recorded growing on Baka land. *D. praehensilis* and *D. semperflorens* are the most important species in the Baka diet (Table 2). These species are annuals that have annual stems and tubers with starch reserves that peak during the dry season (Hamon *et al*. 1995; McKey *et al.* 1998; Dounias 2001). Therefore, in the study area, the period from November to April is suitable for the harvesting of these yams (Dounias 2001; Yasuoka 2006a). In general, annual species tend to grow in drier and more open environments; however, *D. praehensilis* and *D. semperflorens* are also distributed in forest areas (Dumont *et al*. 1994; Hamon *et al*. 1995; Dumont 1997). Among the species that have perennial stems and tubers and grow mostly in densely forested areas, *D. burkilliana* and *D. mangenotiana* are the most important in the Baka diet (Table 2). Their tubers reach the maximum size on an irregular basis so they are harvestable throughout the year. All these species multiply through sexual propagation, using winged seeds that spread out to surrounding areas. Some of them use vegetative propagations, i.e. via bulbils or stolon (Table 1). In addition, all of them can be reproduced by transplanting parts of tubers.

Investigation of the Distributions and Densities of Wild Yams

The distributions of wild yams were investigated at two long-term *molongo* campsites (Mongungu and Jalope

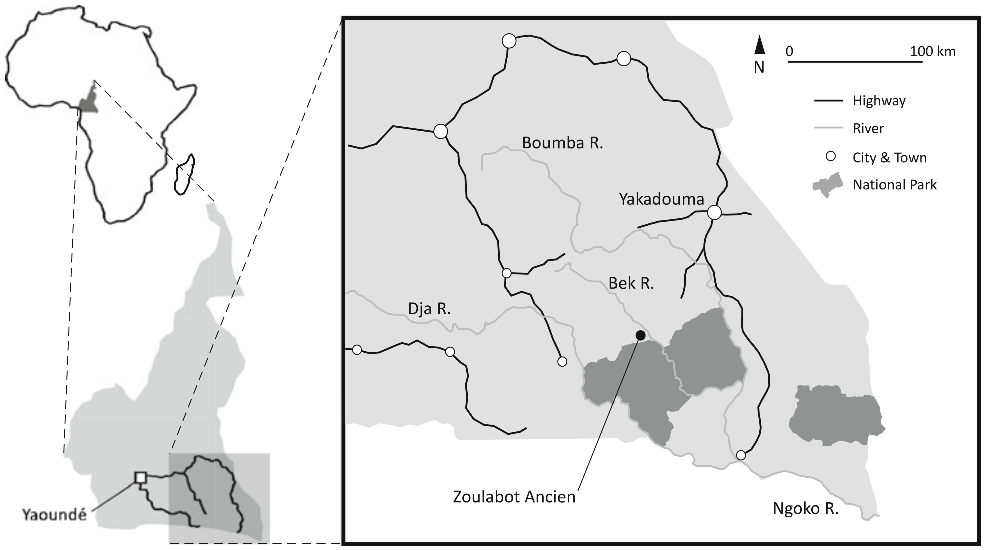

Fig. 1 Southeastern Cameroon and the study site. As well as the highways described, there are many secondary roads, most of which are constructed and maintained by logging companies

camps) I had studied in the dry seasons of 2002 and 2005 (Yasuoka 2006a, 2009a). The total period of occupation was 73 nights, of which 43 nights were spent at Mongungu camp, located 40 km from the village. The diet at this camp consisted solely of wild products, of which 60 % (on a calorie basis) consisted of the two annual yams (Yasuoka 2006a, 2009a). The same was true for the Jalope camp in 2005 (Fig. 2). Compared to farming camps, annual yam consumption in *molongo* camps is considerable (Table 2) and provides more calories than the typical village diet (Yasuoka 2009a, 2012).

At both campsites 24 adjoining quadrats of 10×10 m^2 were set (Figs. 3 and 4). The positions of all yams were plotted, and the species name, height, and diameter of each stem were recorded. The area of the camp and the positions of huts (*mongulu*) were also plotted according to my previous illustrations and the recollections of Baka assistants. To calculate the density of wild yams separately inside and outside the camp, the quadrats were divided into smaller quadrats of 2.5×2.5 m^2, and each quadrat was assigned inside or outside the camp. As garbage was discarded within a few meters from the camp boundary, quadrats on the boundary were judged to be inside the camp.

All plant species observed in four quadrats at the center of each site were recorded. Plant names were first recorded in Baka and later their Latin names were identified

Table 1 Edible wild yams (*Dioscorea* spp.) in Baka land

Species	Baka name	Habitat	Stem	Tuber	Propagation mainly by
D. hirtiflora Benth.	ʔè sèngè	Open area	Annual	Annual	Seed, bulbil
D. semperflorens Uline	ʔè sùmà	Forest and open area	Annual	Annual	Seed, bulbil
D. praehensilis Benth.	sapà	Forest and open area	Annual	Annual	Seed
D. mangenotiana Miège	ba	Forest	Biennial	Perennial	Seed
D. burkilliana Miège	kɛ́kɛ	Forest	Perennial	Perennial	Seed
D. minutiflora Engl.	kuku	Forest	Perennial	Perennial	Stolon, seed
D. smilacifolia De Wild. and Dur.	ɓalɔ̀kɔ̀	Forest	Perennial	Perennial	Stolon, seed
D. sp.	njàkàkà	Forest	Perennial	Perennial	Stolon, seed
D. sp.	ʔè pàngɛ	Forest	Perennial	Perennial	Stolon, seed
D. sp.	ɓɔlì	Forest	Perennial	Perennial	Seed

According to Hladik and Dounias (1993), Hamon *et al.* (1995), Dounias (1993, 2001), Yasuoka (2006a, 2009a)

Table 2 Harvested wild yams in *molongo* long-term camps and farming camps

Species	*Molongo* Mongungu camp		*Molongo* Jalope camp		Farming camp near village	
	2926.0 adult-days		1247.5 adult-days		314.5 adult-days	
	Total (kg)	Per adult-day (g)	Total (kg)	Per adult-day (g)	Total (kg)	Per adult-day (g)
D. praehensilis	3891.0	1,330	1218.0	976	6.1	19
D. semperflorens	654.6	224	963.2	772		
D. burkilliana	184.7	63	66.9	54	11.0	35
D. mangenotiana	61.8	21	78.9	63	48.6	154
D. minutiflora	22.7	8	2.5	2	5.5	17
D. smilacifolia			1.4	1		
Dp. cumminsii	3.1	1	7.4	6	2.9	9
Total	4817.8	1,647	2338.3	1,874	73.9	235

Recalculated from the data analyzed in Yasuoka (2006a, 2009a). *Dp. cumminsii* is a plant that has yam-like edible tubers

(Letouzey 1976; Yasuoka 2009b; Brisson 2011; Hattori 2012). The characteristics of each plant were inferred from the knowledge of the Baka assistants.

Assessment of the Light Environment of Yam Patches

To determine the change in the light environment after the camp was abandoned, hemispherical photographs were taken on the four vertexes and the center of each quadrat in both campsites (61 points for each site, but five photographs could not be taken at the Jalope site because of the presence of a river). Each point was judged to be inside or outside of the camp according to the same criterion as the yam density estimation. In addition, 10×10 m^2 quadrats were set at three campsites abandoned one or a half year previously, and photographs were taken on the four vertexes and the center of each quadrat (15 points in total). Photographs were also taken in the same way in four adjoining 10×10 m^2 quadrats (13 points) set in mature forest with a closed canopy. Finally, as a control plot that represented general light levels

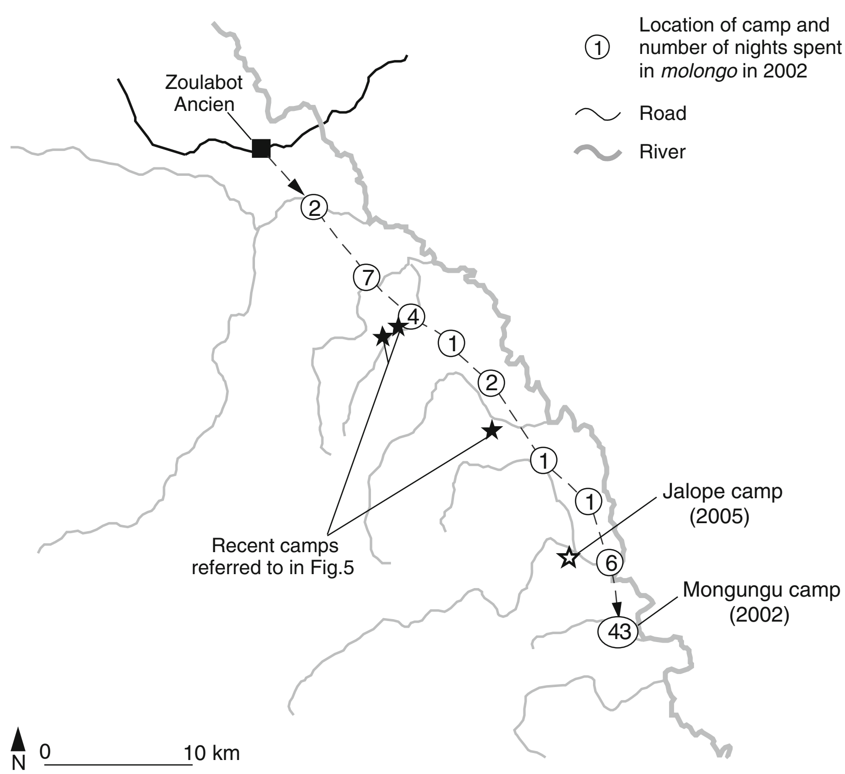

Fig. 2 Routes and camps of the *molongo* from Feb. 17 to Apr. 27, 2002 (Yasuoka 2006a)

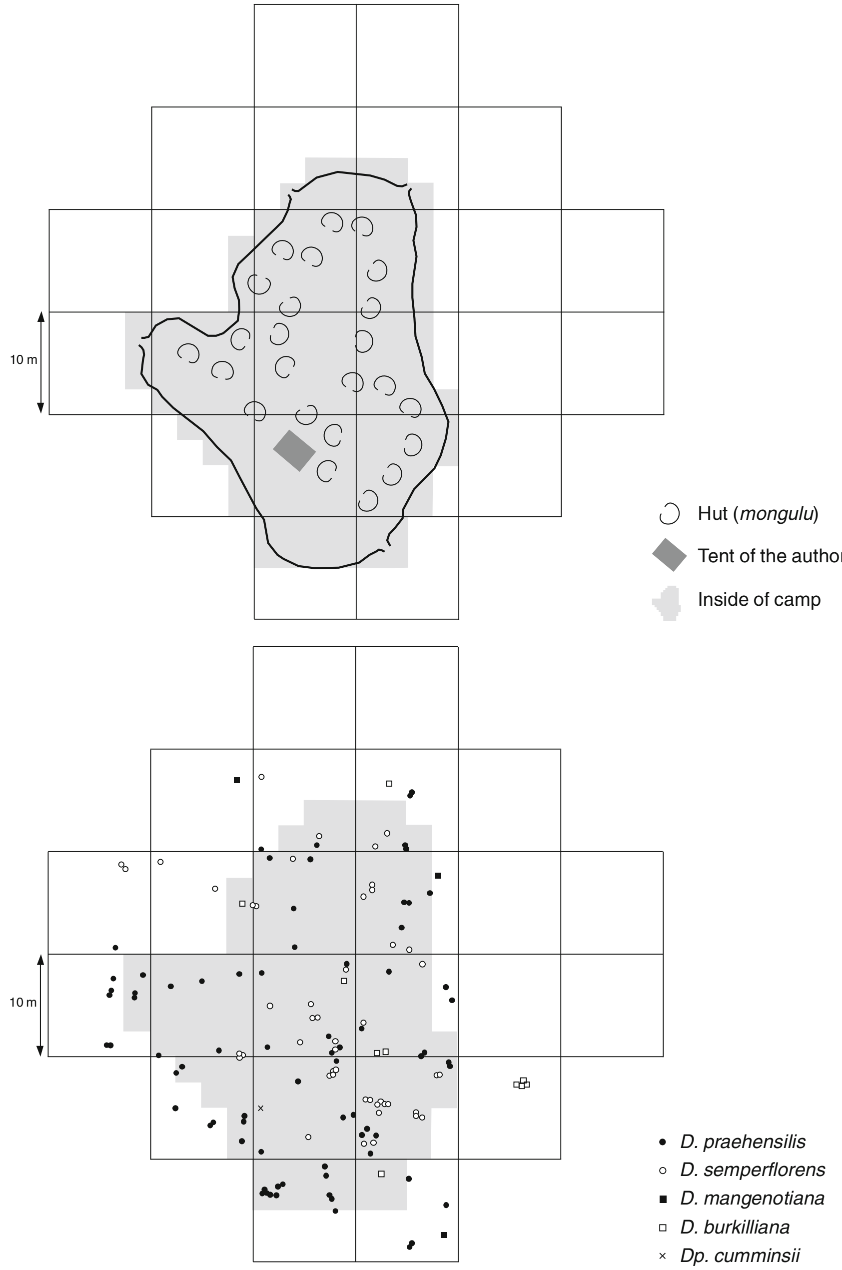

Fig. 3 Distribution of huts in 2002 (above) and wild yams in 2012 (below) at the Mongungu site

in the forest, photographs were taken on a 10 m grid in a quadrat of 50×50 m^2 set at a distance of 200 m from the Jalope site (36 points).

Photographs were taken with a Nikon digital camera (COOLPIX 4500) with a Nikon fisheye lens (FC-E8). The camera was positioned horizontally at 1 m height, and underexposed photographs were taken. CanopOn2 software (http://takenaka-akio.cool.ne.jp/etc./canopon2/) was used to compute the proportion of diffuse solar radiation reaching a given location relative to a location in the open. A standard overcast sky model was assumed, which weights each direction according to the surface of the sky vault fraction and assumes a decrease in light intensity from zenith to horizon; the zenith is three times lighter than the horizon. To compare the light levels among the plots, differences in the distributions of measured light levels were tested using the Kolmogorov–Smirnov test ($p<0.05$).

Results

Distributions and Densities of Wild Yams

At both sites, large numbers of annual yams (*D. praehensilis* and *D. semperflorens*) were observed, whereas other species were much less common (Tables 3 and 4). At Mongungu, 137 stems of six species were recorded, including 75 *D. praehensilis* and 41 *D. semperflorens* (excluding seedlings).

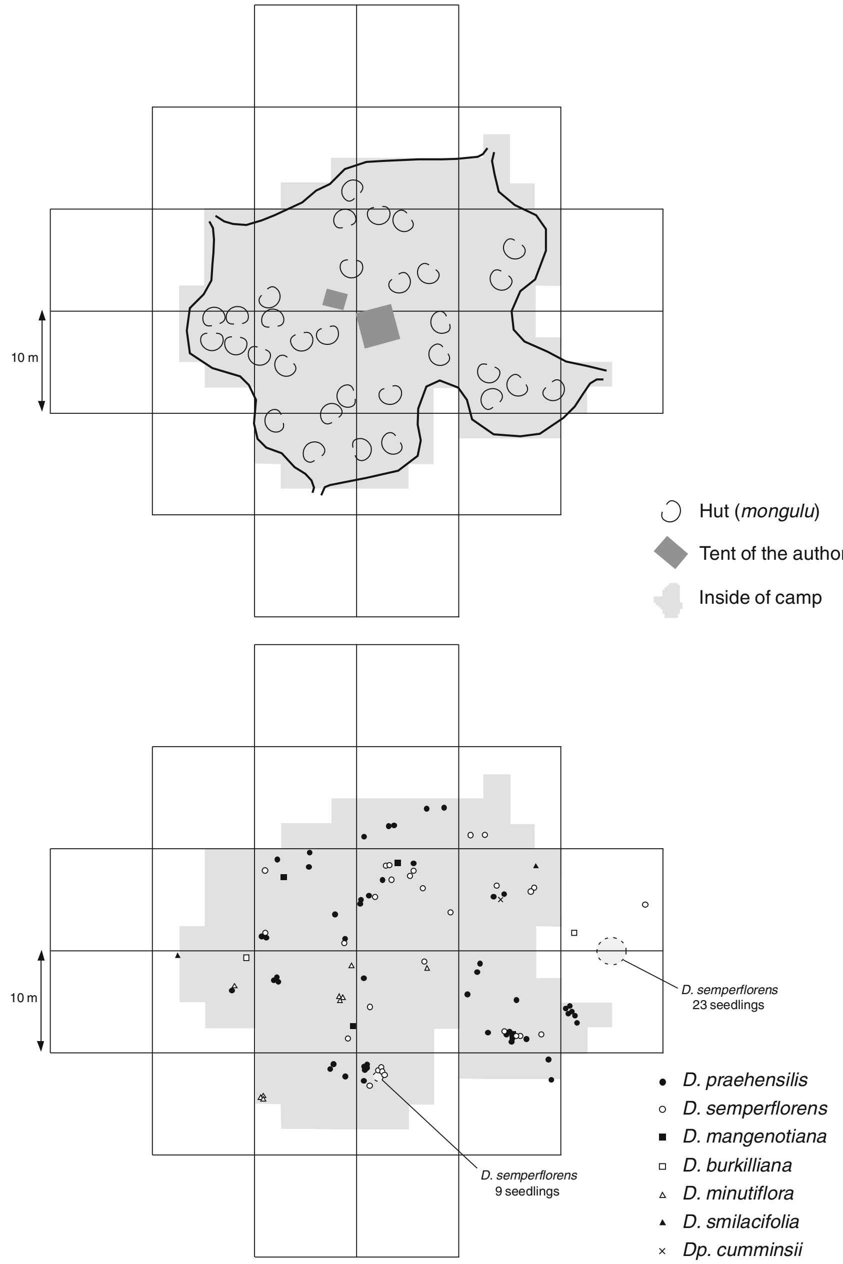

Fig. 4 Distribution of huts in 2005 (above) and wild yams in 2012 (below) at the Jalope site

At Jalope, 129 stems of eight species were recorded, including 50 *D. praehensilis* and 29 *D. semperflorens*. It is obvious that these results correspond to the large quantities of these species consumed during *molongo* (Table 2).

The distribution of yams was concentrated in the inside plots at both sites (Figs. 3 and 4). For *D. praehensilis* and *D. semperflorens*, 57 and 36 stems were observed inside Mongungu camp, whereas 18 and 5 were observed outside the camp, respectively (Table 3). Similarly, 49 and 28 stems were observed inside Jalope camp, respectively, while only one stem of each species was observed outside the camp (Table 4). The respective densities of these yams in the inside plots were 661 and 417 stems/ha at Mongungu, and 509 and 291 stems/ha at Jalope. In the outside plots, their densities were much lower. The density of *D. praehensilis* in the outside plots of Mongungu exceeded 110 stems/ha, but this was only because many yams were scattered on the periphery of the camp (Fig. 3). In addition to these structured surveys, areas within 20 m from the quadrats at both sites were also searched, but neither *D. praehensilis* nor *D. semperflorens* was found.

These distributions of annual yams correspond to the Baka explanation of the formation of yam patches. At the camp, each woman cuts cylindrical tubers into several pieces and boils them in a pot. Harvested tubers are cooked and eaten in a couple of days, because they are quite perishable. The Baka assistants, who had participated in the *molongo*, stated that they had never planted yams but had discarded inedible parts of the tubers around the huts, and

Table 3 Numbers and densities of wild yams observed at Mongungu

Species	Inside (0.08625 ha)		Outside (0.15375 ha)	
	Number of stems	Density (stem/ha)	Number of stems	Density (stem/ha)
D. praehensilis	57	661	18	117
D. semperflorens	36	417	5	33
D. semperflorens (seedling)	7	81		
D. burkilliana	5	58	5	33
D. mangenotiana			3	20
Dp. cumminsii	1	12		
Total	106	1,229	31	202
Total (excluding seedlings)	99	1,148	31	202

Dp. cumminsii is a plant that has yam-like edible tubers

also, according to my observations, they had not planted any tubers in the camp.

Light Environment

The light levels of recently abandoned camps were significantly higher than all other plots (including the control) (Fig. 5). At Jalope, which was abandoned 7 years before the study, the light levels inside the camp were significantly higher than at the control site, whereas the measurements outside the camp were not different from the control. At Mongungu, which was abandoned 10 years before the study, the light levels both inside and outside the plots were not significantly different from the control site. This suggests that light levels revert to their original state over a period of between 7 and 10 years.

Table 4 Numbers and densities of wild yams observed at Jalope

Species	Inside (0.09625 ha)		Outside (0.14375 ha)	
	Number of stems	Density (stem/ha)	Number of stems	Density (stem/ha)
D. praehensilis	49	509	1	7
D. semperflorens	28	291	1	7
D. semperflorens (seedling)	9	94	23	160
D. smilacifolia	9	94		
D. mangenotiana	4	42		
D. burkilliana	1	10	1	7
D. minutiflora	1	10	1	7
Dp. cumminsii	1	10		
Total	102	1,060	27	188
Total (excluding seedlings)	93	966	4	28

Dp. cumminsii is a plant that has yam-like edible tubers

However, the plots inside Jalope were significantly different from the recently abandoned camps, and not significantly different from the outside plots or from the plots at Mongungu. This indicates that even though the light levels were still higher than at the control site, substantial ecological succession had occurred in the inside plots at Jalope. Considering the presence of a fallen tree (50 cm diameter) at Jalope, which fell after the camp had been abandoned, the light levels may decrease more remarkably in the same period.

The distribution of measured light levels in the control plot had a wider range, including lighter points than areas in the forest with a closed canopy, although the difference was not significant.

Vegetation

In eight quadrats from both sites, 120 species other than yams and yam-like plants were recorded. Of these, 21 appeared in five or more quadrats (Table 5). These included shade-tolerant species that had existed before the camps were established, and pioneer species that had established after the camps were abandoned. The latter included fast-growing shrubs and trees, such as *Oncoba glauca*, *Discoglypremna caloneura*, *Dichostemma glaucescens*, and *Tricalysia coriacea*, which resulted in a decrease in light levels at the forest floor. However, they did not affect light levels in higher layers of the forest, because they were still smaller than 5 m in height. Indeed, the yam vines tended to climb these shrubs and use them as props.

Discussion

Human Impacts on Wild Yam Dispersal

The densities of yams in *molongo* campsites were much higher than recorded in previous studies conducted in the western Congo Basin, especially those recorded in mature forest, where annual yams rarely establish (Hladik *et al.* 1984; Hladik and Dounias 1993; Sato 2001; Yasuoka 2009a). As for disturbed environment, Dounias (2001) observed a secondary forest containing yams at a density of 393 stems/ha, in which *D. praehensilis* was dominant; and Sato (2006) described a yam patch on an open hilltop with a density of 602 stems/ha, 94 % of which were *D. praehensilis*. The densities found in the present study far exceed these values: 1,148 stems/ha at Mongungu and 966 stems/ha at Jalope (excluding seedlings), with annual yams being dominant at both sites. In addition, the high density of *D. semperflorens* was an interesting difference from the results of Dounias (2001) and Sato (2006). Obviously, this is the result of intensive consumption of

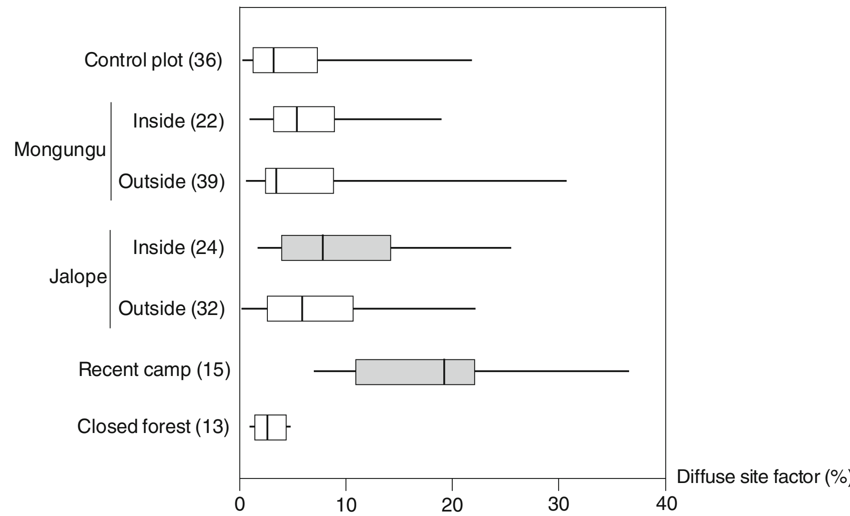

Fig. 5 Comparison of light levels. *Boxes* mark median values and 25th and 75th percentiles, and *whiskers* mark the minimum and maximum. *Numbers* after the plot names indicate points where photographs were taken. Plots with significantly different light levels from the control plot are indicated by *gray boxes* (Kolmogorov–Smirnov test, $p<0.05$)

D. semperflorens, as well as *D. praehensilis*, in the *molongo* camps (Table 2).

The present study also found that light levels on the forest floor reverted to their original state within 10 years or less after camps were abandoned. Nevertheless, the improved light levels do increase the opportunity for discarded yam tuber pieces to regenerate. Once the yams have fully developed, low light levels on the ground will not affect them because the stems grow higher than the surrounding trees and the leaves are well spread. In contrast, the rapid degradation of light levels on the forest floor negatively affects the propagation of yams through true seeds (sexual propagation), which have a lower capacity to establish than tuber seeds (vegetative propagation).

Table 5 Major plant species observed at Mongungu and Jalope

Species	Baka name	Occurrence (0–8)	Habit	Habitat
Aframomum spp. (Zingiberaceae)	njíyi	8	Herb	Gap
Haumania danckelmaniana (Marantaceae)	kpàsɛlɛ	8	Liana	Gap
Rinorea welwitschii (Violaceae)	ngindi	8	Shrub	Shade
Scorodophloeus zenkeri (Caesalpinioideae)	mìngègyè	7	Tree	Shade
Tricalysia coriacea (Rubiaceae)	ngbɛ́ɛ	7	Shrub	Gap
Millettia sanagana (Faboideae)	ngánda	7	Shrub	Shade
Streblus usambarensis (Moraceae)	ndúndu	7	Shrub	Shade
Sarcophrynium brachystachyum (Marantaceae)	ngoasa	7	Herb	Gap
Discoglypremna caloneura (Euphorbiaceae)	jìlà	6	Tree	Gap
Oncoba glauca (Flacourtiaceae)	gbàgɔ̀lɔ̀	6	Shrub	Gap
Lasiodiscus mannii (Rhamnaceae)	èsumà	6	Shrub	Shade
Xylopia sp. (Annonaceae)	gbɛgbɛlɛ	6	Shrub	Shade
Hypselodelphys zenkeriana (Marantaceae)	lìngɔ̀mbɛ̀	6	Liana	Gap
Rourea obliquifoliolata (Connaraceae)	túkusà	6	Liana	Shade
Dichostemma glaucescens (Euphorbiaceae)	mòngamba	5	Tree	Gap
Alchornea floribunda (Euphorbiaceae)	yàndo	5	Shrub	Shade
Anthonotha macrophylla (Caesalpinioideae)	popolo	5	Shrub	Shade
Manniophyton fulvum (Euphorbiaceae)	kusa	5	Liana	Gap
Millettia barteri (Faboideae)	mòkɔkɔdi	5	Liana	Shade
Leptaspis cochleata (Gramineae)	ndingbɛlɛngbɛ	5	Herb	Gap
Palisota megaphylla (Commelinaceae)	njayà	5	Herb	Gap

Grey band indicates the trees and shrubs of pioneer species that have grown up after the camping. This table excluedes wild yam species

Moreover, yam plants remained in and around the camps for 7–10 years after their initial establishment. This indicates that their large-scale propagation has not succeeded, or at least its extent is limited. These results also support the argument that the dispersal ability of annual yams is too low to vigorously colonize forest gaps (Yasuoka 2009a). Therefore, it is likely that the discarding of tubers created dense yam patches in areas that lack wild yams. These results suggest that exploiting annual yams substantially contributes to their dispersal, and that annual yams have been dispersed principally by hunter-gatherers.

Dispersal of Annual Yams by Hunter-Gatherers

There are two important points to note about the dispersal of yams through the activity of the Baka. First, the scattering of the parts of the tubers that are always cut off when yams are cooked is sufficient to create a yam patch. Although the Baka do not have any clear intention to create yam patches in this way, they understand that patches will develop after a *molongo* camp has been abandoned. However, even if they did not recognize the significance of this process, the Baka or their ancestors would have dispersed yams once they began eating them.

Second, this is a direct introduction of tuber seeds into a new habitat. This point is important because annual yams have low dispersal abilities and at the same time they prefer forest gaps with high light levels (Yasuoka 2009a). It has been suggested that Bantu cultivators' land use practices, which induce larger forest disturbances, may have influenced the dispersal of annual yams (Yasuoka 2009a). However, the cultivators, whose food staples consist largely of plantains and cassava, do not grow wild yams in their fields at present, and it is likely that they have never planted them. As noted above, the dispersal of annual yams through true seeds is much less efficient than that through tubers. Therefore, it is likely that the consumption of annual yams by hunter-gatherers would have contributed to their dispersal through the forest.

The Ecological Basis of *Molongo*

The results also indicate that there is an ecological basis of *molongo*, which can be explained at least partially through the Baka's exploitation of yams. The next question is whether enough yam patches to support a series of annual *molongo* can be generated solely by the activity of the *molongo* itself.

First, the number of yam patches required for an annual *molongo* was estimated assuming a group of 50 people (the average size of a Baka settlement) (Sato 1992; Tsuru 1998). The daily food consumption of 50 people is equivalent to that of 35 adults, assuming the same ratio of children that I identified in earlier work (2006a, 2009a). An adult eats 1.5 kg of tubers a day (Table 2); therefore, 35 adults will consume 9,450 kg in 180 days during the November to April period when annual yam tubers remain at their maximum size (Dounias 2001; Yasuoka 2006a). On average, a *D. praehensilis* plant produces tubers of 6.6 kg (Yasuoka 2009a) or 4 kg (Dounias 2001) and a *D. semperflorens* plant produces tubers of 3.1 kg (Yasuoka 2009a). Here, it is assumed that each plant produces 3 kg of tubers. A yam patch contains a combined total of 100 plants of *D. praehensilis* and *D. semperflorens* (Tables 3 and 4), so it provides 300 kg of tubers. Therefore, 32 patches are required to produce 9,450 kg of tubers. However, since a 3-year interval is required to produce a sustainable harvest (Dounias 2001; Yasuoka 2006a), 96 patches are required for an annual 6-month-long *molongo* by 50 people.

Next, how long a patch needs to persist was considered. Generally, the Baka change campsites every two months (Yasuoka 2006b), so a 6-month-long *molongo* includes three long-term camps and the subsequent generation of three yam patches. If the patches can be used repeatedly for 32 years on average, the stocks from 96 patches are always available for the Baka to carry out 6-month-long *molongo* every year. Therefore, we need to determine whether ecological succession progresses to the point that photosynthesis becomes difficult for annual yams due to competing plants and resulting reduction in available light. Light levels on the ground revert to the original state within 10 years after a camp is abandoned due to fast-growing shrubs reaching a height of 5 m (Fig. 5). However, this period is sufficient for new yam plants to regenerate and grow over surrounding shrubs. Moreover, the Baka often cut down several trees 10 to 15 m in height during their stay in a camp, which improves the light levels in the middle layer that are maintained for longer than on the ground. Therefore, it is likely that once a yam patch is established, it will persist for 30 years or more.

The estimated density of yam patches under these assumptions corresponds to field observations. To provide wild yams for 50 people for 2 months (2,100 adult-days), 10.7 patches are needed (cf. 32 patches for 6 months). In total, 11 patches were observed within a radius of 3 km (about 28 km^2) of the Jalope *molongo* camp, where 1247.5 adult-days were spent (Yasuoka 2009a). Assuming a yam patch density of 0.4 (=10.7/28) per square kilometer, a forest of 320 km^2 would contain 96 patches, which meets the requirements of the annual 6-month-long *molongo* for 50 people. The population density is then 0.15 (=50/320) per square kilometer. This is also similar to the density observed at the study site, where an area of 1,000 km^2 was used by

200 people (0.2 people/km^2).[1] These results suggest that enough yam patches to support the annual *molongo* can be generated wholly by the activity of the *molongo* itself.

Toward the Historical Ecology of Rainforests

On this basis, it is possible to move beyond the dichotomy between pure hunter-gatherer subsistence and a dependence on agriculture. As noted above, studies in southeastern Cameroon have indicated that sufficient wild yams were available for hunter-gatherer subsistence throughout the year (Sato 2001, 2006; Yasuoka 2006a, 2012; Sato *et al.* 2012), and the results presented here conclusively show that the activities hunter-gatherers themselves generate this sufficiency.

More importantly, this study provides two conclusions that advance the historical ecology of the African rainforests. First is the significance of "semi-cultivated" resources, which are not domesticated but persist under substantial interactions with humans. This study suggests that hunter-gatherers have depended on the rainforest ecosystem as a habitat through the exploitation of resources such as wild yams along a continuum ranging between pure gathering and complete cultivation depending on local conditions.

"Para-cultivation" of wild yams (Dounias 2001) is an example of such variability. The Baka sometimes rebury part of a yam tuber with the intention of promoting its regeneration. As Dounias (2001) emphasized, para-cultivation does not necessarily lead to complete cultivation but rather remains in an initial state or can revert back to a gathering state if conditions change. Compared to the period when the Baka lived in smaller and migratory settlements in the forest, the population is now more concentrated around the village, and it is unlikely that the Baka's exploitation has led to the accumulation of enough genetic mutations in yams to adapt to conditions under high population density (Yasuoka 2012). Without para-cultivation as the case in Zoulabot Ancien, to maintain yam patches requires considerable distances between settlements and yam patches to avoid negative human impacts on the formation of yam patches.

The second conclusion is a consequence of external factors in the distribution of forest resources. The Baka's resource use and thus the distribution of annual yams have been influenced by a variety of political and economic factors, i.e., their relationship with cultivators, sedentarization, road construction, commercial logging, and forest conservation projects. If the Baka were not sedentarized, their method of yam exploitation would be different. The *molongo* I described in earlier work (2006a) is neither their original hunting-and-gathering lifestyle nor the pure hunting-and-gathering lifestyle that depends heavily on the environment.

For other Pygmy groups that do not engage in *molongo*, it is possible that yam patches were developed but then disappeared with changes in resource use. The Aka, in northern Congo-Brazzaville, do not eat *D. praehensilis* as frequently as the Baka, and they also consume considerable amounts of agricultural crops during the dry season (Kitanishi 1995). For the Mbuti, in eastern Congo-Kinshasa, the dry season is their hunting season and they obtain agricultural crops in exchange for the meat they hunt (Ichikawa 1983). However, the current absence of yam patches does not necessarily mean they never existed.

Yam patches in southeastern Cameroon can also diminish if the Baka cease using them. There are two significant factors that decrease the frequency of *molongo*. One is the expansion of cultivation. The dry season is the suitable period for clearing fields and it falls within the *molongo* season. The second factor is the forest conservation projects that have been promoted since the 1990s (Ichikawa 2006; Njounan Tegomo *et al*. 2012). In 2005, Nki National Park was established adjacent to Zoulabot Ancien (Fig. 1) and *molongo* became illegal because camping in national parks is prohibited.

The *molongo* of the Baka presents a challenge in understanding and preserving the inscribed histories of interactions between the people and forest resources of the African rainforests. This challenge must be addressed to improve existing forest conservation schemes, which have significant and often negative effects on the lives of forest peoples.

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[1] Bahuchet *et al*. (1991) estimated the density of the Aka in the Central African Republic to be 0.1 people/km^2.

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